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Original Article

Cognitive Games: The Effects on Executive Functions and Problem- Solving Skills in Children with Specific Learning Disorders

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Abstract

The present study was set out to explore the effectiveness of cognitive games in the executive functions and problem-solving skills of children aged 8 to11 years with specific learning disorders. Utilizing a quasi-experimental design with pre-test and post-test assessments, the research involved 45 students selected through convenience sampling from special education and rehabilitation centers in Qazvin during the academic year of 2022-2023. Participants engaged in a game therapy intervention consisting of 12 sessions, each lasting 50 minutes, and were evaluated using the Tower of London and the Wisconsin Card Sorting Tests. Data analysis included multivariate and univariate analysis of covariance and paired t-tests, conducted using SPSS version 27. The results revealed no significant differences in the impact of cognitive games on executive functions and problem-solving skills among the three groups (dyslexia, dysgraphia, and dyscalculia) ($p > 0.05$). However, cognitive games significantly improved the executive functions of the dyscalculia group from pre-test to post-test ($p < 0.05$), while effects on the dysgraphia and dyslexia groups were not significant ($p > 0.05$). Additionally, cognitive games positively influenced the problem-solving skills of children with dyscalculia and dysgraphia groups ($p < 0.05$), but had no significant effect on the dyslexia group ($p > 0.05$). Overall, the findings suggest that cognitive games can enhance executive functions and problem-solving skills in children with specific learning disorders, particularly in those with dyscalculia.

Keywords

Cognitive games
Executive functions
Problem-solving skills
Specific Learning disorders

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Introduction

Specific Learning Disorders (SLDs) are identified as prevalent neurodevelopmental disorders that significantly impact numerous societies, leading to substantial challenges for affected children in their comprehension of concepts and the acquisition of various skills, despite their often average or above-average intellectual capabilities (Akbarifar et al., 2019). The Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), categorizes these challenges as specific learning disorders, which are further delineated into distinct subtypes, including dyscalculia, dyslexia, and dysgraphia. According to the American Psychiatric Association, a formal diagnosis of a specific learning disorder is warranted when one or more of these difficulties persist for a minimum duration of one academic year. Problem-solving skills, a critical cognitive skill, plays a vital role in academic achievement and daily life success. It involves identifying appropriate solutions to problems through processes such as analyzing the issue, gathering relevant information, evaluating options, and selecting the best course of action. Successful problem-solving can utilize mathematical algorithms, empirical methods, specialized knowledge, or personal experience, making it a skill that can be developed over time (Soares et al., 2018).

Research indicates that effective problem-solving positively influences social adaptation, motivation, and academic performance among students. Furthermore, there is evidence linking problem-solving skills to self-regulation and success in school tasks, as well as reduced social communication difficulties (Tarazi et al., 2023). However, students with specific learning disorders often exhibit significant challenges in problem-solving, leading to adverse academic, behavioral, and social outcomes (Chieffo et al., 2023) . Studies have shown that these children perform worse in problem-solving tasks compared to their typically developing peers (Molinini et al., 2021), other researchers also confirming their

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deficient performance in this area (Parhoon et al., 2019).
The intersection of learning disorders and neuropsychology has prompted researchers to explore cognitive psychology and neuroscience to better understand the underlying causes of learning disorders. Various studies have examined cognitive processes and their relationship with learning difficulties (Crisci et al., 2021), drawing attention to the structure of executive functions. Executive functioning, a neuropsychological concept, encompasses several cognitive processes essential for learning and problem-solving, including attention and working memory. The term "executive" was first introduced by Pribram in 1973 to describe the functions of the prefrontal cortex, and since then, various authors have articulated similar concepts under different terminologies (e.g., Meltzer's "executive function," Dawson & Guare's "executive skills," and McCluskey's "executive functions") (Friedman & Robbins, 2022).
Many researchers have defined executive functions using different theoretical models and cognitive processes (Salehinejad et al., 2021). Some adopt unitary or process-oriented models focusing on how multiple skills or components work together to complete complex problem-solving tasks, while others use multifaceted models emphasizing the core skills involved in executive functions and distinct processes. Evidence supports both models, with literature indicating that studies on students often distinguish between various factors such as working memory and processing speed, although there is support for both unitary and multifaceted models of executive functions. Generally, executive functions are viewed as a unitary construct with decomposable components (Spiegel et al., 2021). Students with specific learning disorders frequently exhibit significant deficits in executive functions, including working memory operations, impulse control, and cognitive shifting, which hinder their ability to access information, organize, prioritize, and coordinate information during simultaneous cognitive activities (e.g., writing). These children often struggle with self-regulation, lack effective problem-solving strategies, and demonstrate limited cognitive flexibility (Lonergan et al., 2019). Additionally, students with specific learning disorders face challenges in metacognitive skills, which manifest in ineffective planning, self-monitoring of learning, and error recognition and correction (Drigas et al., 2022).
Interventions for cognitive and behavioral disorders focus on teaching or enhancing the cognitive skills necessary for learning (Narimani et al., 2016; Wiest et al., 2022). Most interventions involve educational activities aimed at helping children learn skills and develop learning plans based on their strengths and cognitive areas needing intervention (Roberts et al., 2022). Therapists often target specific cognitive abilities through practice on graded activities to improve cognitive performance (Bonnechère et al., 2021). Sometimes, specialists guide children through pencil-and-paper activities, which can resemble school or home tasks, potentially leading to fatigue and disengagement, negatively impacting treatment outcomes and adherence (Moll et al., 2016). Therefore, game therapy is proposed as a more effective intervention. Play-based learning refers to teaching-learning activities conducted in formal or informal educational settings through games designed explicitly to achieve educational goals. This method includes games that are not merely for entertainment but are used to pursue learning objectives and enhance cognitive development (Shrinivasa et al., 2018).
It is essential to recognize that play is a vital tool for children's growth, serving as a serious endeavor that can be evaluated. Play is a pleasurable and enjoyable activity crucial for holistic development. It is a natural learning method through which children experiment, gain experience, draw conclusions, and learn. Moreover, play nurtures creativity, focus, and the ability to discover relationships between objects and their surroundings, while also reducing anxiety, increasing motivation, and providing opportunities to test solutions (Teymoori et al., 2022; Yogman et al., 2018). Significant research studies have explored the real relationships between various types of play and the achievement of specific learning goals (Parker et al., 2022).
In this context, the present study focuses on cognitive games, also known as mental games, which require the application of thinking and reasoning skills (Martinez et al., 2023). Utilizing cognitive games in formal educational settings can enhance students' reasoning abilities, defined as "key" skills that underpin most learning tasks, thereby contributing to academic progress and alleviating learning disorders (Sun et al., 2023). Based on existing studies, play-based learning interventions can effectively improve mathematical concepts and problem-solving skills in students with specific learning disorders (Miller, 2018). Thus, it can be concluded that employing cognitive-behavioral game therapy methods may effectively address writing, handwriting, reading, and mathematical challenges faced by students with specific learning disorders, preparing them to tackle academic issues (Azizi et al., 2020).
Given the aforementioned considerations and the observed research gap regarding the effectiveness of cognitive games on executive functions and problem-solving skills of children with specific learning disorders, this study aims to address the question: Do cognitive games influence the executive functions and problem-solving skills of children with specific learning disorders?

Method

Participants

This study employed a quasi-experimental design with a pre-test and post-test framework to assess the effectiveness of cognitive games in executive functioning and problem-solving skills in children with specific learning disorders.
The study's population consisted of 466 children aged 8 to 11 years diagnosed with specific learning disorders who were receiving education at special education and rehabilitation centers in Qazvin during the academic year of 2022-2023. A total of 45 children were selected through convenience sampling and randomly assigned to

three groups of 15 participants each: dyscalculia (15), dysgraphia (15), and dyslexia (15).

Instrument

Tower of London Test:

Developed by Shallice (1982), assesses executive functioning, particularly planning and problem-solving skills, especially in individuals with frontal lobe lesions. It consists of two boards with three rods and three colored beads, where participants must rearrange the beads to match a predetermined configuration using the fewest moves possible. The test includes 12 problems, with required moves ranging from 2 to 5. Psychometric evaluations demonstrate strong construct validity and high reliability, confirming the test's effectiveness in measuring executive function deficits https://doi.org/10.1007/s10072-017-2957-y.

Wisconsin Card Sorting Test (WCST):

Developed by Berg et al. in 1948, is a widely recognized assessment tool for evaluating cognitive abilities and executive functions, specifically the ability to adapt strategies in response to changing environmental demands. The test includes either 60 or 64 response cards paired with four stimulus cards, and participants must achieve a specified number of categories, with the examiner rearranging cards as necessary. Standardized scoring and normative data for the 64-card version were established in 1993, covering a broad age range from 6.5 to 89 years. Psychometric evaluations confirm the WCST's strong validity in measuring executive function and cognitive flexibility, alongside high internal consistency and robust test-retest reliability https://doi.org/10.3758/s13428-021-01551-3.

Table 1. Structured Protocol

Session	Game Name	Objectives	Content
1	SET	Enhance cognitive skills, improve reasoning ability, and strengthen adaptation and comparison skills	Engage in the SET game
2	SuperDuz	Strengthen reasoning, problem-solving skills, planning, decision-making, focus, attention, and visual intelligence	Engage in the SuperDuz game
3	Zoom	Increase recognition and adaptation skills, enhance concentration, accuracy, and reaction speed	Engage in the Zoom game
4	Othello	Strengthen working memory, enhance visual memory, and improve concentration	Engage in the Othello game
5	Instant	Increase attention, concentration, and reaction speed, enhance adaptation skills, and strengthen the right hemisphere of the brain	Engage in the Instant game
6	Creative Think	Enhance memory, creativity, attention, analytical skills, and deductive and logical reasoning	Engage in the Creative Think game
7	Emotion Tower	Strengthen cognitive flexibility, working memory, attention, concentration, planning, and problem-solving	Engage in the Emotion Tower game
8	Loonpos	Pattern recognition, enhance visual memory, attention, concentration, and strengthen logical, mathematical, spatial, and visual intelligence	Engage in the Loonpos game
9	Sharp Eye	Strengthen visual memory, increase accuracy, attention, concentration, and reaction speed	Engage in the Sharp Eye game
10	Color Sudoku	Enhance logical decision-making, improve IQ, increase accuracy and concentration, and strengthen problem-solving skills	Engage in the Color Sudoku game
11	Hand Sorting	Strengthen short-term memory, enhance visual memory, increase reaction speed, concentration, and boost self-confidence	Engage in the Hand Sorting game
12	Pentago	Spatial visualization, engage the right hemisphere of the brain, enhance problem-solving skills, logical thinking, and geometric and mathematical skills	Engage in the Pentago game

Procedure

The inclusion criteria for participants were: (1) age between 8 and 11 years; (2) parental consent for participation; (3) a diagnosis of specific learning disorder confirmed by specialized evaluators at the educational and rehabilitation centers, following referrals from school teachers; (4) enrollment in the aforementioned centers; and (5) normal intellectual functioning as determined by clinical assessments conducted by specialized evaluators.

Exclusion criteria included: (1) failure to meet any of the inclusion criteria; (2) absence from more than two intervention sessions; (3) presence of any physical or psychological disorders; and (4) uncorrected visual or auditory impairments. In order to analyze the data, SPSS software (Version 27) and multivariate covariance analysis, univariate covariance analysis and paired t-test were used.

Results

The study's sample comprised 45 children aged 8 to 11 years diagnosed with specific learning disorders, categorized into three distinct groups: Dyscalculia, Dyslexia, and Dysgraphia. The results presented in this section provide insights into the effects of the intervention on these groups.

Table 2, provides essential demographic data, including age, gender distribution, and pre- and post-test scores for executive functions and problem-solving skills across three groups: Dyscalculia, Dysgraphia, and Dyslexia. The demographic characteristics highlight the diversity in age and gender among participants, which is crucial for understanding the context of the findings. The significant differences in pre- and post-test scores across groups can guide further analysis of the effects of cognitive games.

Table 2. Demographic Characteristics and Research Variables of Participants

	(Mean ± SD)		
Variable	Dyscalculia Group	Dysgraphia group	Dyslexia Group
Age	80.04 ± 1.9	98.67 ± 0.9	74.87 ± 0.9
Gender			
- Female	8	6	9
- Male	7	9	6
Executive Functions			
- Pre-test	11.67 ± 1.4	44.73 ± 1.4	87.06 ± 1.4
- Post-test	91.40 ± .5	46.13 ± 1.5	40.06 ± 1.5
Problem-solving skills			
- Pre-test	38.40 ± 3.27	72.67 ± 2.27	77.27 ± 3.27
- Post-test	66.80 ± 1.31	39.00 ± 2.30	93.05 ± 5.29

Table 3. presents the results of the covariance analysis, indicating that the differences in post-test executive function scores among groups are not statistically significant after controlling for pre-test scores and the findings suggest that cognitive games do not significantly impact executive functions in children with specific learning disorders across the three groups, leading to the acceptance of the null hypothesis.

Also, in order to investigate intra-group changes, an intra-group design (correlated t) was used from pre-test to post-test for intra-group changes of executive functions, the results of which are presented in Table 4.

Table 3. Results of Covariance Analysis for Post-Test Executive Functions After Adjusting for Pre-Test Scores

Source of Variation	Sum of Squares	df	Mean Square	F	Sig	η^2
Pre-test	2.453	1	2.453	1.846	0.182	0.043
Group	0.688	2	0.344	0.259	0.773	0.012
Error	54.480	41	1.329	–	–	–
Total	1327.00	45	–	–	–	–

Table 4, shows the results of the paired samples t-test, indicating significant improvement in the Dyscalculia group's executive functions post-intervention, while the Dysgraphia and Dyslexia groups did not show significant changes. In other way the significant improvement in the Dyscalculia group suggests that cognitive games may enhance executive functions specifically for children with math disorders, while the lack of significant results in the other groups indicates a potential limitation of the intervention.

Table 4. Results of the Paired Samples t-Test for the Impact of Cognitive games on Executive Functions in Children

Index	Phase	Mean	Standard Deviation	t	df	Sig	Effect Size (Cohen's d)
Dyscalculia Group	Pre-test	4.67	1.11	2.58	14	0.022	-0.667
	Post-test	5.40	0.91				-0.649
Dysgraphia group	Pre-test	4.73	1.44	0.88	14	0.395	-0.227
	Post-test	5.13	1.46				-0.221
Dyslexia Group	Pre-test	4.87	1.06	1.33	14	0.205	-0.344
	Post-test	5.40	1.06				-0.344

Table 5, provides results indicating no significant differences in post-test problem-solving skills among the groups after adjusting for pre-test scores and the findings confirm that cognitive games do not have a significant effect on problem-solving skills among the three groups, reinforcing the conclusion drawn from the executive function analysis.

Also, in order to investigate intra-group changes, an intra-group design (correlated t) was used from pre-test to post-test for intra-group changes of Problem-solving skills, the results of which are presented in Table 6.

Table 5. The Results of Post-test Covariance Analysis of Problem-Solving Skills After Adjusting for the Pre-test

Source of Variation	Sum of Squares	df	Mean Square	F	Sig	η^2
Pre-test	0.044	1	0.044	0.004	0.951	0.001
Group	33.622	2	16.811	1.450	0.246	0.066
Error	475.289	41	11.592	–	–	–
Total	42584.00	45	–	–	–	–

Table 6, presents the results of the paired samples t-test, showing significant improvements in problem-solving skills for the Dyscalculia and Dysgraphia groups, but not for the Dyslexia group. In other words, the results indicate that cognitive games effectively improve problem-solving skills for children with dyscalculia and dysgraphia, suggesting targeted interventions may be beneficial for these groups.

Table 6. Results of the Paired Samples t-Test for the Impact of Cognitive games on Problem-solving Skills in Children

Index	Phase	Mean	Standard Deviation	t	df	Sig	Effect Size (Cohen's d)
Dyscalculia Group	Pre-test	27.40	3.38	4.26	14	0.001	-1.101
	Post-test	30.80	1.66				-1.071
Dysgraphia group	Pre-test	27.67	2.72	2.77	14	0.015	-0.714
	Post-test	30.00	2.39				-0.695
Dyslexia Group	Pre-test	27.27	3.77	1.61	14	0.129	-0.417
	Post-test	29.93	5.05				-0.405

Discussion

The primary objective of this research was to examine the effectiveness of cognitive games in executive functioning and problem-solving skills in children with specific learning disorders. The findings revealed that while there were no significant differences in the impact of cognitive games on executive functioning among the three groups (dyslexia, dysgraphia, and dyscalculia), the within-group analysis indicated that cognitive games had a significant positive effect on the executive functioning of children with dyscalculia disorders, as evidenced by improvements from pre-test to post-test. Conversely, the effects on the executive functions of the dysgraphia and dyslexia groups were not statistically significant, suggesting that while there was some improvement, it was not sufficient to be deemed meaningful.

These results align with previous studies by, (Jafari et al., 2022) and (Rachanioti et al., 2018), which also reported positive effects of cognitive games on executive functions. However, they contrast with findings from (Sabzi et al., 2022), (Hosseinkhanzadeh et al., 2018), (Chutko et al., 2022) and (Berninger et al., 2017), which highlighted varying outcomes.

Research has consistently shown that cognitive games can positively influence the executive functioning of children with specific learning disorders. For instance, a study demonstrated that engaging in a game called "Cognitive Control" significantly improved executive functioning in preschool children with specific learning disorders (Scionti et al., 2020). Similarly, another researchers found that a game named "Headsprout" enhanced executive functioning in children on the autism spectrum, focusing on tasks such as planning and problem-solving, which are crucial components of executive function (Hansen et al., 2023).

The underlying mechanism by which cognitive games affect executive functioning is believed to involve the stimulation of the prefrontal cortex, the brain region responsible for executive functions, which is often underactive in children with specific learning disorders. Cognitive games necessitate problem-solving, attention, and working memory, thereby activating and strengthening neural connections within the prefrontal cortex. Additionally, these games can enhance self-regulation and impulse control, which are essential aspects of executive functioning. Children with specific learning disorders may struggle with these skills, but engaging in cognitive games allows them to practice and improve these abilities. Overall, cognitive games provide an effective, enjoyable, and engaging means for children with specific learning disorders to enhance their executive functions and cognitive skills.

Furthermore, the results indicated that regarding the impact of cognitive games on problem-solving skills, there were no significant differences among the three groups (dyslexia, dysgraphia, and dyscalculia). However, the within-group analysis revealed that cognitive games significantly improved problem-solving skills in children with dyscalculia and dysgraphia disorders, as indicated by enhancements from pre-test to post-test. In contrast, the effect of cognitive games on the problem-solving skills of the dyslexia group was not significant, despite some improvement noted from pre-test to post-test.

These findings are consistent with those of), (Jafari et al., 2022), (Yazdani, 2022), and (Morin et al., 2017), who also reported positive effects of cognitive games on problem-solving skills in children with specific learning disorders.

Research indicates that cognitive games can effectively enhance problem-solving skills among children with specific learning disorders. For instance, a computer game designed to improve executive functioning skills, including problem-solving, planning, and decision-making, resulted in significant improvements for these children (Araiza-Alba et al., 2021). Another study found that cognitive games improved problem-solving skills in children with ADHD, suggesting that such games may help these children develop better attention control and cognitive flexibility—critical skills for effective problem-solving (Benzing & Schmidt, 2019). Overall, cognitive games appear to be a valuable tool for enhancing the problem-solving skills of children with specific learning disorders. However, it is essential to note that not all games are created equal, and some may be more effective than others. Therefore, it is crucial to consider the insights of cognitive science professionals when selecting games for intervention.

Certainly, the mechanism by which cognitive games influence problem-solving skills in children with specific learning disorders is related to the activation of various cognitive processes in the brain. When children engage in cognitive games, they must utilize their problem-solving skills, which involve identifying problems, generating and evaluating potential solutions, and selecting the best course of action. This process activates several cognitive functions in the brain, including attention, working memory, and cognitive flexibility. These cognitive processes are vital for effective problem-solving and are often impaired in children with learning disorders. By participating in cognitive games, children can practice and enhance these cognitive processes, thereby improving their problem-solving skills.

Moreover, cognitive games provide a safe and low-risk environment for children to experiment with different

problem-solving strategies and learn from their mistakes. This type of learning, known as "trial and error," has been shown to be effective in improving problem-solving skills. In summary, the impact of cognitive games on the problem-solving skills of children with specific learning disorders is associated with the activation of various cognitive processes in the brain, as well as the opportunity to practice and learn from mistakes in a safe environment.

Conclusion

This study highlights the effectiveness of cognitive games in enhancing executive functioning and problem-solving skills in children aged 8 to 11 with specific learning disorders. Significant improvements were noted in executive functioning for children with dyscalculia, while dyslexia and dysgraphia showed minimal effects, suggesting a need for tailored interventions. Furthermore, cognitive games positively impacted problem-solving skills in dyscalculia and dysgraphia, though results for dyslexia were less significant. These findings align with existing literature, emphasizing the potential of cognitive games to stimulate critical cognitive processes and enhance learning. Future research should focus on optimizing game selection based on cognitive science principles to maximize effectiveness, advocating for the integration of cognitive games into therapeutic practices for children with specific learning disorders.

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